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B3-2 Impurity Concentrotion Profiles of Diffused Boron and Phosphorus in SiO_2/Si and Poly Si/SiO_2/Si Structures Measured by Auger Electron Spectroscopy

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The diffusion of impurities in SiO_2/Si structures has been analyzed by many investigators using the two-boundary diffusion model related with oxide masking effects in planar technology. However, very few have been reported on the actual impurity concentration profiles in the oxides. (1)-(4)

Recently, silicon gate MOS devices have been widely used in integrated circuits. However, impurities diffuse into the gate oxide from the doped polycrystalline silicon layer and sometimes penetrate through the oxide into the silicon substrate resulting in instabilities and large threshold voltage shifts. From the point of view of the device fabrication, it is very important to know the amount and the penetration depth of the impurities in the oxide.

This paper describes the profiles of the diffused impurities of boron and phosphorus in SiO_2/Si and poly Si/SiO_2/Si structures obtained with Auger electron spectroscopy (AES). The impurity profiles in the oxide of SiO_2/Si structures were also measured by using an ion micro analyzer (IMA) for boron and radio tracer analysis for phosphorus to compare with the results obtained by AES.

P-type wafers for phosphorus diffusion and n-type wafers for boron diffusion were oxidized at 1100 °C and 1200 °C in dry oxygen ambient. For the poly Si/SiO_2/Si structures, a polycrystalline silicon layer of 3000 Å in thickness was deposited following the oxidation. Boron or phosphorus was diffused into the SiO_2/Si and poly Si/SiO_2/Si structures with varying temperature and time. B_2H_6 and BN were used as boron diffusion sources and $POCl_3$ as a phosphorus diffusion source. Rightly after diffusion, the samples for AES were cut from the wafers. The in-depth profiles were obtained by repeating Auger measurement and Xe ion milling.

In Figure 1, a typical in-depth profile of boron taken by AES is shown. Boron was diffused into a 850 Å oxide at 1050 °C for 17.5 minutes with B_2H_6 as a diffusion source. The oxide thickness after diffusion was measured to be 1125 Å. As shown in Figure 1, boron peaks at the Si-SiO_2 interface and the concentration at the peak was calculated to be 8.5×10^{21} /cm^3. Further experiments showed that the peak height increases with diffusion temperature and time and a flow of B_2H_6. The lower peak and the faster penetration were also observed with B_2H_6 than with BN. This is due to the enhanced diffusion in H_2 ambient. Figure 2 shows an in-depth profile obtained from the same wafer by IMA. The results obtained with AES and IMA agree with each other very well.

Figure 3 shows a typical in-depth profile of phosphorus diffused into a 1000 Å oxide at 970 °C for 10 minutes. Nitrogen of 1.6 liters/min was flowed through $POCl_3$ which was kept at 20 °C. Simultaneously, oxygen of 1 liter/min and nitrogen of 2 liters/min were flowed into a

phosphorus diffusion tube. The thickness of the oxide after diffusion was measured to be 1300 Å. A strong fluctuation of the phosphorus concentration is seen in the figure. The same phenomenon has been observed by other investigators. This fluctuation could be explained by the phase segregation and the formation of phosphorus compounds in the SiO_2-Si system[3].

The concentration profile of boron in a poly $Si/SiO_2/Si$ structure is shown in Figure 4. The diffusion was carried out at 1050 °C for 45 minutes. The thickness of the polycrystalline silicon layer and the oxide were 3000 Å and 1000 Å respectively. BN was used as a boron source with flows of nitrogen of 2 liters/min and oxygen of 8 cc/min. The boron diffusion resulted in the growth of an oxide layer of 900 Å on the polycrystalline silicon layer. The boron profile in the oxide is very similar to the phosphorus concentration profile as shown in Figure 3. The concentration of boron is calculated to be 2.5×10^{21} /cm^3 in the polycrystalline silicon layer. This value is about 5 times larger than the solid solubility of boron in a single crystal silicon substrate. As shown in Figure 4, boron accumulates at the poly Si-SiO_2 and Si-SiO_2 boundaries.

More details will be given at the conference.

References:
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3. P. F. Schmidt et al., J. Electrochem. Soc. 115 (1968) 79.
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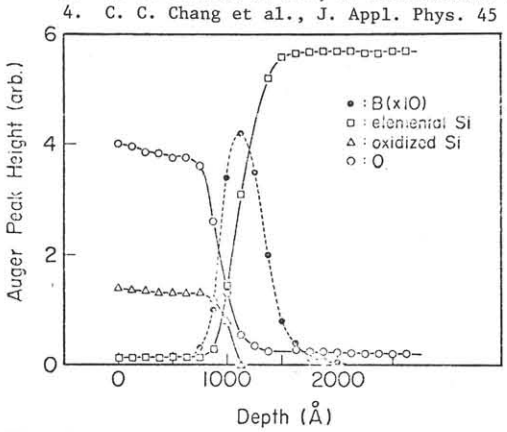

Fig. 1. In-depth profile of B in SiO_2/Si (AES).

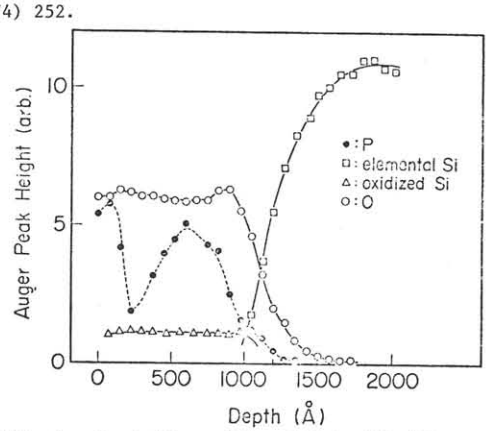

Fig. 3. In-depth profile of P in SiO_2/Si.

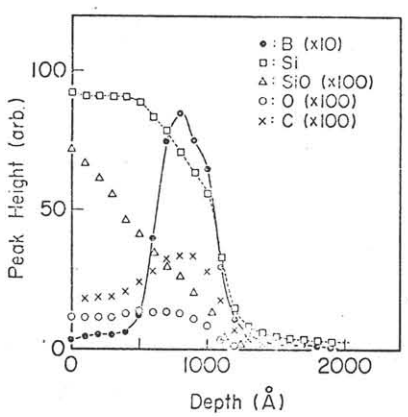

Fig. 2. In-depth profile of B in SiO_2/Si (IMA).

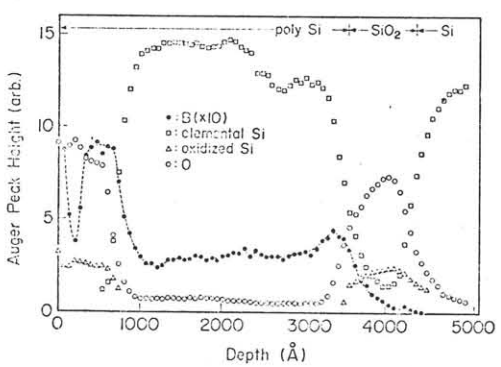

Fig. 4. In-depth profile of B in poly $Si/SiO_2/Si$.